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ABSTRACT

This paper presents a study using a neo-Piagetian theory to analyze the micro-structure underlying Piaget's "control of variables" scheme. Data are presented which support the conclusion that young children are capable of acquiring and utilizing this scheme before they acquire Conservation of Weight, that is, providing (1) that the children are at least 7-8 years old; (2) that they are field independent and (3) that they have been exposed to previous situations in which an uncontrolled test was conducted and the ambiguity of the results was made apparent. The results are discussed with regard to Piaget's theory of development and the limitations of development on learning. (Author/CS)

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An Experimentally Induced Reversal in the Normal Sequence of Development

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According to the neo-Piagetian theory developed by Pascual-Leone (1970), a child's success in problem-solving depends on three distinct factors: (1) the repertoire of figurative, operative and executive schemes (internalized facts, rules and strategies) to which he can assimilate the problem, (2) his ability to coordinate these schemes, and (3) his cognitive style, particularly his degree of field dependence or independence (cf. Witkin et al, 1962).

The present paper will be concerned primarily with the second of these factors, and the potential it provides for predicting the effects of experience on the acquisition of specific Piagetian structures. According to the theory, a child's capacity to coordinate schemes increases linearly with age, and is relatively independent of specific experience. The modal values at various age levels are indicated in Table 1 (Pascual-Leone, 1970, Case, 1972b).

Other things being equal, the size of a child's coordinating capacity determines the earliest age at which he first solves a problem. For example, Conservation of Weight is not normally solved until the age of 9 or 10. This is because the normal strategy for solving it requires the coordination of four operative and figurative schemes (cf. Case, 1972a). Experience, when it affects the difficulty of a problem, does so not by increasing the child's coordinating capacity, but by providing him with a more sophisticated set of schemes, such that the strain on his available capacity is reduced. How this can occur is best illustrated with a specific example.

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Consider the Flexibility of Rods problem designed by Inhelder and Piaget (1958), in which children are first allowed to become acquainted with the relative flexibility of a set of rods varying along five dimensions, and then asked to demonstrate the effect of each variable individually, by setting up comparisons between appropriate rod pairs. For a naive subject, the solution of this problem might require the coordination of almost any number of schemes, depending on the nature

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of the repertoire to which he assimilated it. For a sophisticated subject, however, the problem could be solved simply by looking at the rod pairs which differ in each particular dimension, and selecting one where no other significant difference between the rods was apparent. The function of experience would be to provide subjects with the executive and other schemes necessary for the execution of this routine. Since a total of only 3 figurative and operative schemes need be coordinated in order to execute the routine (see Table 2), the theory would hold that field independent 7- and 8-year-olds could learn to apply it successfully; providing, that is, that the demands placed on their coordinating capacity in the actual learning situation were not exceeded. This point requires some elaboration.

Within the traditional Piagetian framework, it is normally assumed that 8-year-olds can not acquire a repertoire of schemes such as that described in Table 2 due to the mismatch between the formal structural properties of these schemes, and the general developmental level which the children have attained. Within the neo-Piagetian framework, however, it is assumed that any new insight can become a schematized and integrated part of a child's repertoire at any developmental level, providing (a) that he has a sufficient mental capacity to arrive at this insight by the coordination of other schemes already in his repertoire, and (b) that he encounters experience which challenges him to effect this coordination, and to consolidate and apply the insight which results from it.

In order to understand the prerequisites for constructing the appropriate repertoire of schemes (particularly the executive), consider the following imaginary situation.

> Gerry and John are twelve-year-olds. They have a footrace which Gerry wins. Turning to John, Gerry says, "See, now I've proved I'm a better runner." John replies: "You have not. You're slower and you know it. You only won because you were wearing Addidas."

A child who understood that Gerry might just appear to be the faster runner, even though he was actually slower, would have constructed precisely that insight which underlies the executive described in Table 2, since he would, in effect, have rejected an uncontrolled test due to its ambiguity. As is shown in Table 3, this insight can be acquired by the coordination of only three schemes, all of which may be presumed to be available to the field independent 7- or 8-year-old. The prediction may be generated, therefore, that such subjects should be able to understand why the race doesn't prove John is faster. They should subsequently be able to execute the strategy described in Table 2 for applying this insight, provided that they receive sufficient opportunity to analyze situations similar to that provided by the footrace, and to set up better races or tests themselves.

Table 4 presents the results of an experiment which was designed to test this assertion. The 7- and 8-year-olds were selected so as to

exhibit the normal pattern of cognitive development for their age group: they all passed Conservation of Substance but failed Conservation of Weight. Similarly, the 5- and 6- year-olds were selected so as to exhibit the normal pattern for their age group: they all failed both Conservation of Weight and Conservation of Substance. The field independent subjects were selected so that their scores would be at least one standard deviation above the normal mean on the WISC blocks.[2] The field dependent subjects were selected so that their scores would be at least one standard deviation below the normal mean on the same measure. Half the subjects (uninstructed) were administered the Flexibility of Rods test directly, with no check as to their initial repertoire of schemes. The other half (instructed) were first led through a sequence of four training sessions which presented them with situations like that mentioned in the footrace example.

As may be seen, the data were very strong, and in complete conformity with the neo-Piagetian theory. The majority of field independent (instructed) 7- and 8-year-olds passed the test. The majority of field independent (instructed) 5- and 6-year-olds did not. The performance of the field dependent subjects, and of the uninstructed subjects, was intermediate between the two extremes. This same pattern held up on a second transfer test (Spinning Wheels cf. Inhelder & Piaget, (1958)) and on a delayed posttest two months later.

Since traditional Piagetian theory holds that the general sequence of intellectual development is invariant, it is clear that the aberration produced in the present study is most easily treated as being only an apparent one. The simplest interpretation is to assume that the subjects who failed Conservation of Weight had preliminary concrete operations (as indicated by the fact that they passed Conservation of Substance) and that they passed the Flexibility of Rods task by using one subset of these operations (perhaps Grouping VII). While this reasoning can explain the apparent developmental reversal obtained as a result of the treatment, however, the fact remains that it has never actually been applied to predicting such an occurrence. In fact, precisely the opposite prediction has been made, and by Piaget himself (Inhelder & Piaget, 1958, p.62; Hall, 1970, p.30) Two conclusions may therefore be drawn:

1. The first is that global logical analyses of Piagetian knowledge structures should be supplemented by specific functional analyses of the processes necessary to acquire and utilize them. Development should be seen as setting an absolute limit, not on the specific logical structures which can be acquired, but rather on the processes by which this may be done.

2. The second is that the neo-Piagetian model proposed by Pascual-Leone should be given serious consideration as providing a new system on which the functional analysis of children's thought may be based.

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2. The reasons for considering the WISC blocks to be a measure of field dependence are given in Witkin et al (1962), and Pascual-Leone, 1969.

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Table 1

Maximum Number of Schemes Which Can Be Coordinated (M) at Any Given Age Level

Age	Piagetian Substage	M
5-6	preoperations	e+2*
7-8	early concrete operations	e+3
9-10	late concrete operations	e+4
11-12	early formal operations	e+5
13-14	middle formal operations	e+6
15-16	late formal operations	e+7

*In this notation, the numeral refers to the maximum number of figurative and operative schemes which can be coordinated. The constant e refers to the minimum capacity required for an overlearned executive which can effect this coordination.

Table 2

Schemes Required for Execution of Control of Variables Routine

Kind of Scheme	#	Content of Schemes
Executive	e	General goal: determine effect of one variable in the presence of others. General method: select pair such that no counter-explanations for effect are possible.
Figurative	1	Representation of specific relevant differences in rod array.
Operative	2	Specific routine for searching for any difference other than X.
Figurative	3	Representation of the specific difference (X) permitted on this trial (e.g., length).

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Table 3

Schemes Required for Acquisition of
Control of Variables Insight
(Executive in Table 1)

Kind of Scheme	#	Content of Scheme
Executive	e	General goal: understand John's conclusion. General method: scrutinize his statements and think about them.
Figurative	1	Representation of John's first assertion: Gerry is slower.
Figurative	2	Representation of John's second assertion: Gerry's shoes are faster.
Operative	3	Compensation rule*: if two opposing effects meet, the strong overpowers the weak and disguises it (unless they are equal).

*A scheme such as this may be inferred from subjects' compensation responses to Piaget's Conservation of Substance problems.

Table 4

Percentage of Subjects Passing the Flexibility of Rods Test On Their First Exposure to It. (N = 51)

Subject Characteristics	Instructed	Uninstructed
Field Independent, 7-8 (n=20)	80*	20
Field Dependent, 7-8 (N= 16)	13	25
Field Independent (n_1 = 10; n_2 = 5	0	0

*Note: for all cells % passing Conservation of Weight = 0.

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